Summary

This report studies ways of improving the reliability of the date of delivery in batch mechanical engineering* and shortening the delivery period promised to the customer. Delivery promises must be regarded as sacrosanct.

The incentive to improve both delivery reliability and delivery time is the increased profitability and efficiency of the suppliers' operations that result, and the enhancement of the company's reputation with customers at home and abroad. This direct relationship between deliveries and profits may surprise some readers; the explanation is set out on page 5, and in more detail in Appendix A.

Delivery performance is the responsibility of a company's board and management. Improvement can be attained only if there is determination to achieve it. It requires an integrated policy involving the board and the management of every department. It can be frustrated by lack of communication and co-operation between departments.

Improving delivery is a difficult task calling for new ideas and principles. There must be a change in attitudes; only then can the available techniques be used effectively.

There is a serious lack of appreciation throughout the country of the importance of good delivery. In the case of capital goods it is often more important competitively than price and may even outweigh the intrinsic functional or design aspects.

Comparative delivery performance substantially affects exports and imports. Few overseas competitors have an outstanding reputation for delivery performance, yet where this is achieved the benefit is out of all proportion to the effort required to obtain it.

In Part 1 we outline the general approach if companies are to improve delivery performance. In Part 2, section A, we pose some questions to boards and in section B we suggest some questions for boards to ask their managements. The answers to these will help identify the areas where improvements may be made.

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*Batch production is the predominant practice in mechanical engineering. Furthermore, a significantly large proportion of such output is used by other manufacturers in the assembly of their own products, and any delays in delivery of components, *etc*, can affect the ultimate delivery of the final products.

Basic definitions

There can be varying understandings of the meaning of 'delivery date', thus:

Production personnel sometimes consider it the date when the goods are available for customer inspection, or when handed over to a despatch department.

Sales and contracts staff consider it the date when the goods leave their factory.

The customer's purchasing officers consider it the date when the goods are received at their nominated location.

The first task for management is to see that there is no confusion in the committment entered into, and also that it is *not* in the best interests of the firm's reputation, or that of the country, to have a commercial policy which—either by neglect or intent—allows the supplier and the purchaser to interpret that commitment differently.

Throughout this report 'delivery performance' has generally been used to mean 'completing things on time' but in implementing the recommendations in the report it is the view of the working party that a substantial contribution will be made to reducing complaints on performance if ambiguity is removed by accepting two basic definitions:

Delivery should always be interpreted by suppliers as the date when receipt is required at a location specified by the purchaser; and

Despatch should always be interpreted by suppliers and purchasers as the date when the goods are to leave a specified location.

Part 1 The delivery problem

1.1 As the EDC has frequently stressed, in the case of capital goods the design and performance characteristics of a machine or piece of plant, and the reliability and length of delivery are often more important than price when customers are deciding what to buy. Poor planning and control of operations resulting in uncompetitive delivery performance can frequently lose an order, both at home and overseas, and this is a potent cause of imports.

1.2 For these reasons the Mechanical Engineering EDC decided that a working party drawn mainly from engineering companies, but also including representatives of user industries, should be set up to examine the causes of poor delivery performance and to suggest ways of improvement.

1.3 There has been plenty of criticism, much exhortation, but little constructive comment about delivery performance. It is a basic national attitude that great emphasis is given to prices and costs in considering competitive performance, whereas delivery considerations are little understood or stressed. As a consequence faulty diagnoses are made and the wrong remedies prescribed.

1.4 At the outset, it must be appreciated that the problems to be solved are difficult and complex and are inherent in batch engineering processes. They are not, therefore, peculiar to UK engineering industries and our foreign competitors face exactly the same problems and are also prone to fail to solve them on occasions, as the purchasers of foreign machinery well know.

1.5 The problems can be better appreciated by considering an engineering company manufacturing complex machinery incorporating many parts or bought-in components. The problem of loading machines at the right time and in proper sequence, ensuring rapid through-put, minimum stocks and work in progress is extraordinarily complex and requires first class planning and paper work. At the same time, purchases of castings, forgings, electrics and subcontract components all have to be organised in proper sequence. Any delays by suppliers, or rejects, complicate the company's problems enormously. Clearly, the success of the company in solving these interrelated problems will have a vital bearing on the reliability and length of delivery. *This is why delivery performance cannot be considered in isolation* (any more than, *eg* stock levels can), *but must be reckoned as one aspect of an integrated approach to the whole complex of operating variables. Good and reliable delivery is one of the symbols by which success may be measured and it is intimately related to profitability.*

1.6 Examination of delivery performance, therefore, provides a most effective means of concentrating management attention on operating weaknesses and ways of eradicating them and developing better methods. The reliability and length of delivery are determined by company planning, methods, and management attitudes over the whole range of operations from market forecasting, receipt of order, planning and production, right through to final receipt of the product by the customer. An integrated approach to all these elements is, therefore, essential to good operating practice and delivery performance, bringing about *lower stocks and work in progress, and quicker turnround of working capital. This will result in higher returns on capital employed.* These benefits, together with the greater volume of business which good delivery performance attracts, provide the *incentive* for a company to tackle these complex problems.

A Board and management responsibility

1.7 For this focus on delivery to be effective as an internal management discipline, it is imperative that the company board, not merely senior management, should accept full responsibility for improving delivery performance. *This means the board must accept that they have a problem and that they are determined to solve it.* This must inspire all levels of management and it should be accepted that a record of broken delivery promises is a serious company failure which cannot be tolerated in the interests of customers or the company's optimum profitability.

1.8 Too often boards and managements do not recognise their responsibility for delivery performance and do not devote sufficient attention to the effects on current profitability, capital utilisation and future order levels and the company's future prosperity. The main problem is to convince management that delivery performance can and must be improved. Techniques exist, but first there is the stumbling block of company attitudes and the need for determination and effort to examine critically all their operations affecting delivery performance.

1.9 How the board tackle these problems is their affair; no two companies are exactly alike, but many of the underlying problems have common elements and we consider that broad general guide lines can be laid down. We attempt this in the series of questions which we address to boards, managements *and* customers in Part 2 of this report. We believe that many companies would derive substantial benefit from a close study of these questions and the suggested courses of action.

The obstacles to change

1.10 It will be instructive to consider briefly the attitudes obstructing progress. *First,* is the unthinking attitude that a company with a too long order book is doing well: a condition which is aggravated by the cyclical fluctuations to which engineering business is prone, so that there is an illusory search for security which a too long order book seems to provide. If, however, this long order book produces delivery periods longer than the customer is prepared to accept, a future shortage of orders can be forecast; if it results in a widely held reputation for failure in delivery reliability then to restore the company image may well take years: indeed, unless delivery reliability improves, this may never be achieved.

1.11 The *second* obstacle is the frequent tendency for individual departments to operate in isolation, without a total and well-comprehended plan, and in partial ignorance of what other departments are doing. The main offenders are companies large enough to have a departmental structure which has developed to the stage of having large crevasses between departments into which the delivery promises to customers disappear. 'Ivory tower' thinking, and sectional attitudes must be eliminated. The board and management must be determined to produce an overall plan and be determined to see it through to success in spite of short-term difficulties and, possibly, a temporary drop in profitability. This may well involve the slaughter of some 'sacred cows'—*eg* that maximum machine loading is desirable without taking into account the offsetting costs of the resulting excessive stocks and work in progress on the floor, or despatch reliability.

1.12 The *third* obstacle to improvement is the fact that mechanical engineering is dependent on other industries for its raw materials and many components and many suppliers may also have poor delivery performance. This encourages the attitude that nothing can be done: poor delivery performance caused by direct failures within a company is too easily blamed on its suppliers or outside services. Internal failures are often not self-evident and companies have a surfeit of excuses to blame others for their own failings. In any event, the working party considers it the duty of engineering manufacturers to cater for the shortcomings of their own suppliers, and not to quote these as an excuse.

The motive to change: improved profitability

1.13 The working party firmly believes that exhortation will not succeed in overcoming these resistances to change (industry suffers from too much exhortation), but that the prospect of higher profitability provides the most effective incentive for a change in board and company attitudes and for introducing the sort of improvements we have in mind. The investigations necessary to improve delivery performance will show up many other areas of low efficiency. Improving delivery performance can open the door to these other improvements. Those who have succeeded make it clear that the scope for increased profits can be substantial. An example based on actual operating practice is quoted in Appendix A.

Improved personal relationships

1.14 Poor delivery reliability causes friction between customer, sales, works and purchasing personnel and encourages 'passing the buck' to others and the fabrication of excuses for failures. Inaccurate delivery periods cause frustration in all departments, and apart from friction it means that management spends much time trying to correct yesterday's errors and does not devote time to avoiding them tomorrow. Good delivery performance can improve all personal relationships in a company.

The importance of factual data and advance planning

1.15 Once the board have accepted that they must be intimately concerned with the company's delivery reputation they must take steps to have *regular, objective and accurate* means of informing themselves about actual delivery performance. The details or broad outlines to be presented to the board are matters for each company to decide. The actual planning and provision of facts and information is a management responsibility, but it is essential that the board be involved and be fully conversant with the overall principles and overall plan so that they can adjust their current policies to suit future requirements and steer the plan to suit their own future policies.

1.16 In far too many companies orders are injected by the sales department with delivery dates which are not balanced against production capacity. It is essential *to plan the work and then work the plan.* Production must be planned in advance and must equate the promised output with the available capacity.

Once the plan starts to be implemented, any but minor changes in it will reduce output and result in poor delivery performance.

1.17 *Balancing requirements and capacity is a major necessity for improved delivery performance.* All too often the balance of requirements and capacity is upset by the injection of additional demands to suit a particular customer, resulting in the total destruction of the plan and the balance of requirement and capacity. While plans should be flexible, changes should be made only on senior authority and injections to the programme allocated only after full recognition of the effect on capacity or other orders. This balancing of requirements and capacity is not limited to machine loading, but involves every function, from office paperwork, research and development, design, tooling, purchasing, outside sub-contractors, stockholding, *etc*, to despatch transport. It is useless quoting three months for despatch based on two months for material acquisition and one month machining under conditions of spare machine capacity, if other functions are fully loaded for two months or tooling design and acquisition takes four months.

Techniques

1.18 There are many techniques available and well described for measuring the capacity of each function and the outstanding load on it. The techniques for data processing, purchasing, breaking assemblies into components, stock control, production loading, and scheduling paperwork improvements, *etc*, are well documented. No particular technique for each function may suit every company. It is the duty of management to select those specific techniques which will contribute best to its overall company plan. One technique, however, which would be worth detailed study, and which is *not* widely described in the literature, is 'cellular grouping of machines'. This is briefly described in Appendix B, together with an extract from the James Clayton Lecture to the Institution of Mechanical Engineers on 27 March 1968, by D T N Williamson FRS, which is reproduced by permission.

Product policy

1.19 In batch production factories the facilities are laid out to suit the normal mix of principal products. Like vehicles on a motorway, all products must enter at an appropriate point and travel down the correct lane at the correct speed. Any product which is injected into, or is an obstruction to the smooth flow must be removed if all others are not to be delayed. Therefore, the products which can pass through the batch production facility without problems should be defined and these must be the only products for which the sales department can accept orders without question.

A second category comprises those products for which there is, or will be, a satisfactory market but which do not pass through the present production facility freely. These must be re-designed, or new tooling or production facilities provided.

The third category are the products requested by customers which will not (even after re-design or tooling) pass easily through the production facility. These must be removed from the main batch production facility and produced in a specials department or by sub-contract, and the customer must pay a realistic price. Failure to arrange this will damage the delivery performance of the bulk of the production.

1.20 It cannot be over-emphasised that specials are a substantial cause of poor delivery performance in factories laid out for batch production of standardised items. Sales personnel often like them, as they open up customers' doors for personal discussion. Customers often like them, as they may simplify a single, immediate design or other problem. If they are essential and justify the real cost, the customer will pay, but he must recognise that he is building in a future spares/replacement problem.

1.21 Spares are a most difficult problem, particularly those for items no longer in current production. The production facility must be specially arranged for current spares (ideally with a special department) or planned for, in the case of non-current items. In either case these spares must be realistically priced.

Throughput time

1.22 *Planning should be based on the shortest possible throughput time to ensure that queuing in production is minimised.* Every contract has (or should have) a precise delivery period, and delivery reliability is good only if this period is met. Time wasted or lost by any function, from order receipt to delivery, is irrecoverable and reduces the time available for other functions. In relation to delivery reliability, time lost in administration, design, *etc*, merely reduces the time available for material acquisition or production, or both. But also time lost while materials sit in the stores or on the factory floor as work in progress reduces the time available for materials and components acquisition and destroys planned purchasing with its cost-saving potential. Far too often the purchasing organisation becomes a panic buying activity endeavouring to recover time lost elsewhere. Therefore, to give delivery reliability, or shorter delivery time, a short throughput time is essential. Long factory throughput times also mean that at any one time many items being recorded, searched for, chased, *etc*, add an unnecessary cost to administration, staff, material handling and other overheads.

Stocks and work in progress

1.23 Excessive stocks and work in progress on the shop floor add to working capital requirements. The stock (including work in progress)/sales ratio is higher than it should be and *profitability is thereby reduced.* Company revenue depends on the rate at which output is delivered to customers and paid for. The accumulation of materials and parts on the shop floor represents 'dead' money and a low rate of capital turnover. This results from inefficient scheduling and loading of machines and slow throughput.

Purchasing policy and stock control

1.24 Purchasing policy is of critical importance to good delivery and the prosperity of a company generally. It is intimately linked to stock control. Purchases of materials and components normally account for 40–50 per cent of the sales price and it is essential that this vital function is performed by a man of adequate seniority in the management structure. Delays in supply, poor quality and the rectification of defects are all inimical to good delivery and profitability and more attention should be given to vendor rating and supplier quality assurance.*

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*See *A Guide to Supplier Quality Assurance in Engineering* published by the Institution of Production Engineers, May 1966, price 10s.

Part 2 The questions

2.1 As fellow-industrialists we have addressed these questions to ourselves and recommend other boards and managements to study them carefully. The answers should provide a spur to the necessary corrective action to improve operating efficiency and delivery performance, and, consequently, profitability. We recognise that no two companies are exactly alike and that each company must develop corrective policies to meet its own circumstances, but we are firmly of the opinion that there are common guiding principles and that is why, in addition to posing questions, we suggest possible remedies. *Whilst we unquestioningly place the main responsibility for poor delivery performance on manufacturers,* customers are not always blameless, and we, therefore, also address some questions to them. In this connection it must be borne in mind that because of intertrading, many engineering companies are themselves customers of other engineering, or other firms. Your purchasing manager is your suppliers' customer and the customers' questions could, therefore, usefully be put to him.

A Questions for the board

The facts

2.2 Do we really know the effect of our company's delivery performance on our company reputation, volume of orders, loss of potential markets, exports, or what future policies are necessary to ensure a satisfactory order book and profit?

It is our opinion that one director, amongst his responsibilities, should report to the board on all matters appertaining to delivery performance, in a similar manner to the reports received on accounts, sales, production and research and development. Good delivery performance requires an integrated company policy and is not a departmental matter: it needs one co-ordinated channel for *regular* reports on such things as:

(i) Current delivery reliability.

(ii) Current customer acceptance of quoted delivery periods.

(iii) Orders lost, undue lack of enquiries materialising, or markets which cannot be reached due to inadequate delivery performance.

(iv) The reputation of the company on delivery performance.

(v) How we compare with our competitors on delivery.

The board must, of course, ensure that these reports are honest and objective, without any 'whitewash'.

Total management involvement

2.3 Is our management integrally involved in delivery performance of the company, working to an overall plan, with free communications and co-operation between departments to recover any failures? Or do we have virtually water-tight departments, with departmental managers running their own 'private empires' and blaming other departments for all failures?

Unless the board participates and gives the lead, total management involvement will not occur and delivery performance will not improve.

Board policies

2.4 (i) What broad policy statements have we given management on markets, pricing and products (particularly in relation to non-standard items)?

(ii) Have we given management a precise policy statement on our delivery performance aims and the company reputation we expect them to attain?

If not, we should do so, and have regular reports on progress towards these objectives.

Forecasts

2.5 No doubt companies have the current year's budgets and forecasts of profits, capital and total sales.

(i) Do we have next year's sales forecasts broken down into broad product or production groups balanced against capacity to assist in formulating plans for equipment needed next year but to be ordered now?

(ii) Do we have, say, a five-year sales forecast to assist in longer-term performance and possibly to indicate that changes in policy may be necessary?

Purchasing and vendor appraisal

2.6 In batch production mechanical engineering the purchasing department probably spends between 40–50 per cent of sales income, and delays in delivery from suppliers will be reflected in our own performance.

(i) Are we satisfied that this function is in the hands of a sufficiently senior executive?

(ii) Have we means of measuring the purchasing performance: do we know suppliers' delivery times, particularly for critical major items of raw materials and components?

(iii) Does our purchasing manager submit a report to the board detailing specific difficulties, price and delivery trends, *etc*, and an analysis of supply failures, giving reasons?

It is our opinion that far too often purchasing is in the hands of an 'order clerk' (receiving requisitions from others), with no real authority, except to buy in the cheapest market and with little clear understanding how to measure suppliers' delivery performance and, to some extent, contol it. He can have no influence (except bad) on stock levels. Although strictly a management and not a board matter, we consider that the board should be as much involved in expenditure on materials as they are in capital expenditure. A revenue loss on poor purchasing or surplus or redundant stocks can be more serious than a capital loss on poor plant purchasing.

Materials management and stock control

2.7 (i) Are stock levels determined by financial limits, *ie* budgetary control?

(ii) Do we analyse critically our stock and work in progress levels, not only by comparison with last year or against the budgeted amount, but also in terms of the minimum stock in relation to sales, production capacity and suppliers' delivery times?

If not already in operation, we should consider:

Establishing optimum stock levels for raw materials, bought out items, work in progress and finished stocks.

Asking management whether these levels can be attained or improved; if not, why not?

Greater flexibility, particularly where it is necessary to adjust stock levels temporarily to accommodate lengthening delivery of critical items, but not permitting unnecessary 'contingencies'.

To effect improvements in delivery performance it is essential to ensure that the right materials are available at the right time, remembering that it is cheaper to hold raw materials than parts and sub-assemblies. At a cost this can be done by carrying excessive stock and locking up unproductive capital; but to effect a minimum stock necessitates co-ordination between sales forecasts, finished stock, work in progress, raw stock, bought-out components, stocks and acquisition lead times and other purchasing matters.

To effect real impact on delivery performance, if the company is of adequate size, one executive on an equivalent level to that of production manager or chief accountant should be appointed as materials controller responsible for purchasing, stores, stock control and material scheduling. Our boards should receive reports on the means to effect this co-ordination and the programme to minimise stocks and, particularly, work in progress (and the related tied-up capital), while at the same time ensuring that delivery performance is improved. Alternatively (for smaller companies) boards should appoint a senior man for purchasing. In either event, the person responsible for material supplies should be integrated into the management team.

Board attitudes

2.8 Every company has policies that were laid down, and have continued to be followed, even though changing circumstances may have made them no longer tenable. Our boards should, therefore, examine critically all the conventional beliefs: in particular, balance apparent economies in one department against the higher costs they may cause elsewhere.

Do our boards pass 'sacred cows' down to senior management, which management hesitate to challenge? *eg:*

(i) Expensive machines must be fully utilised (without counting the cost of excessive work in progress).

(ii) Batches must be large enough to minimise setting-up costs even if this results in unnecessarily large stocks of components.

(iii) Certain customers must receive good delivery performance, others do not matter—*ie*, do we arbitrarily disrupt manufacturing programmes in favour of the latest and most influential complaint?

(iv) Are rush jobs accepted without counting the cost, *eg*, in production disorganisation or special transport facilities?

(v) A large outstanding order book is desirable, because it appears to provide security?

B Questions for boards to ask their managements (executive directors and department heads)

2.9 It is not possible because of the differing problems and circumstances of differing companies to list all the questions which you should ask your managements to examine. Therefore the main factors are given in more general terms and each company must extend these to its own detailed problems.

Management attitudes

2.10 (i) Does your delivery performance give your customers what they need and your company a good reputation? If not, are you determined to improve your delivery performance, first as to *reliability* (making your promises as sacred and as binding as the quoted price), and then to improve the delivery *period* knowing that this exercise will involve much time and effort, will not be simple, and may involve the scrapping of traditions or 'sacred cows', possibly changes in staff and management, and other difficulties?

(ii) Do all your staff recognise that delivery performance is a *company* responsibility and that failings are ultimately the responsibility of the chief executive, with delegated responsibility to every departmental head and departmental staff?

If so, you recognise that sales, design, purchasing, production, assembly and despatch are directly involved, and financial and accounting procedures and policies can destroy delivery performance. If not, you have your first problem.

Accuracy of delivery promises

2.11 (i) Are promises made on behalf of the company at different staff levels, each promise being made to the best ability, or to suit the customer or for other reasons? or:

(ii) Are promises the responsibility of one person against *measured facts* of the present loading of the facilities involved including the time for paperwork, design, material acquisition, production capacity, and other functions including delivery transport time?

If (i) applies, the chief executive (or his appointed delegate) has the problem of reorganisation to put responsibility for delivery promises and actual performance under one executive responsible for overall co-ordination in order to reach (ii) above. If (ii) applies, delivery reliability should be good. The development from stage (i) to (ii) may take a year or so to become effective. Then and only then can delivery periods be shortened.

Essentials for overall planning

2.12 (i) Do you have a long-term sales forecast (say, five years) broken down into product groups or production centres to steer capital expenditure and allied policies?

This cannot be meticulously accurate, but should be directionally right. With regular revisions it should be the best guide to policy.

(ii) Do you have a short-term sales forecast (say, 12 months) broken down into product groups or production centres to assess current and potential capacity, or other matters to anticipate problems likely to arise?

(iii) Can you actually *measure*, based on facts, the current load of orders, broken down into product groups or production centres, to give prior knowledge of potential bottlenecks or to allow for sub-contract or other means to avoid the bottleneck failures on delivery?

(iv) Actual measurement means measurement of the actual facts, not estimates drawn from personal opinions or guesswork. Do you really *know* the date on which materials are required, or are some ordered only when shortages are discovered? And does every item to be produced to meet an assembly date, have a date when it must start from raw stores and a date for completion?

Sales influence on delivery performance

2.13 (i) Do you know what orders you have received, what you expect to get this month, this quarter, this year, or in the future? If not, how can others plan now to have the necessary facilities when you want them?

(ii) Do you quote deliveries, in good faith, but based on hopes, rather than facts? Do you accept delivery dates to please your customer or put pressure on others to give a date which may not be feasible and then boast about the volume of orders?

If so, you are deceiving yourselves and the customer, and damaging your company reputation.

(iii) If you quote a feasible delivery date, do you re-check delivery feasibility at the date of order to allow for the effect of other orders, and if other orders make the original promise impossible, have you the courage to tell your customer and risk the loss of an order?

(iv) Do you accept orders with a completion date before all the technical and design matters are clearly defined and the necessary time allowed for this work to be completed?

(v) Do you accept orders which include specifications, inspection, or other time-consuming matters (such as supply difficulties, potential scrap, or extensive test procedures) without providing the time for these in the delivery promise?

(vi) Do your sales personnel accept orders for products which, because of their

nature, interfere with the planned flow of basic product batches and orders? Does their eventual incremental profit justify this inclusion?

(vii) Does everybody recognise the difference between despatch date and delivery date? (See definitions).

Technical and design influences

2.14 Some of these are referred to in paragraph 2.13.

(i) Do you know your capacity, work on hand and completion date for each project, to fit in the overall dates for completion of each part and final despatch of the whole?

(ii) Do you co-operate with sub-contractors (via purchasing) to ensure that your designs and specifications are feasible, not only to avoid unnecessary scrap, but also to make it possible to get the necessary materials by the necessary date? Are your specifications so rigid that purchasing may have to wait months for a particular material when another, equally suitable, is available ex stock (and may be cheaper)? (This is not a once-and-for-all exercise: circumstances, availability and standards change.) Do you have these aspects under constant review, to ease your company's delivery problems?

Accounting influences

2.15 This section may at first sight seem irrelevant, but accounting influences can have a major effect on delivery performance.

(i) Does your costing system show two identical (or similar) machines in different departments with differing rates?

If so, the chances are that one may stand idle while the other has queues of work (largely overdue) to avoid adverse variances in budgetary control systems.

(ii) Does your costing system show that it is cheaper to sub-contract on long delivery rather than produce internally on otherwise idle plant?

This sounds foolish but it does happen.

(iii) Do you worry about expensive plant standing idle, and encourage its full loading even if this results in idle work in progress waiting for subsequent operations, queueing at bottleneck machines, and broken delivery promises?

(iv) What other 'sacred accountancy cows' do you pass down which are not in the interests of good delivery performance?

(v) The accountant's department being largely a data collecting department, do you use any available relevant accounting data to help to balance materials required against stock and orders? or, production times required against committed load, future load and actual available time? (See also data processing.)

Purchasing policy

2.16 In our opinion purchasing personnel are frequently of insufficient seniority in the management group, have inadequate knowledge of the materials required; and in spite of the fact that they spend over 40 per cent of the company's income and are a key function in delivery performance, they are frequently little more than order clerks. (See paragraph 2.17 (iv).)

(i) Do you know sufficiently in advance what is wanted and when? If a delivery date is not feasible, are you prevented from purchasing suitable alternatives by rigid specifications?

(ii) Do you receive requisitions in time to provide feasible delivery, or are you permanently chasing impossible dates for items overlooked by others?

(iii) Do you have time to negotiate the best price, quality and delivery performance from alternative suppliers? Or are you everlastingly chasing bits and pieces to try to recover time lost or other omissions elsewhere in order to complete overdue contracts?

(iv) Have you means of measuring the purchasing performance: do you know suppliers' delivery times, particularly for critical major items of raw materials and components?

Stock control and materials management

2.17 Stock and work in progress in companies in the mechanical engineering industry often lock up over 50 per cent of the employed capital. Good planning and stock control can halve this. Poor stock control and planning are major factors in poor delivery performance.

(i) Have you a stock control system: does the system ensure the accurate recording of stock movements?

(ii) Does the system entail the establishing of optimum stock levels and re-ordering quantities? If so, how often are these levels reviewed, and do they truly reflect production requirements and suppliers' delivery times?

(iii) Do you know the material and bought out components required to meet the production programme, and when they will be required?

(iv) Do you have one senior executive who is responsible for the co-ordination of purchasing, stock, and related functions?

Production control influences

2.18 (i) Is your production in the immediate future planned from available materials and to suit the promised delivery date?

(ii) Is the production plan dislocated by changes imposed because of lack of materials to suit selected customers, or because of pressure from sales personnel, managers or the chairman, without knowledge of the effect of these changes on all other orders?

(iii) Can the factory leave the difficult, inconvenient or unpopular item until the customer squeals loudly enough?

(iv) If a change of plan is desirable and endorsed by the appropriate authority, have you got the flexibility to deal with the consequences?

(v) Do production control personnel spend their time chasing the results of past errors and have neither time nor facilities to plan the future?

Data processing

2.19 (i) Can you effect improvements in time and accuracy by centrally co-ordinated paperwork?

A lot of paperwork is involved in exploding orders received into their assemblies, components and materials in stock or to be purchased, and the allocation of these into orders, with every activity planned and dated.

Often each department does its own paperwork by clerical or mechanical methods. Time consumed this way, and duplication in different departments can lead to increased costs and discrepancies. A central system may be based on simple comptometer equipment, or a computer, if the load is big enough. A computer, however, is only a machine, and although vastly quicker, it can only be as effective as the data input is adequate and accurate.

(ii) Can you introduce part-numbering or number suffix coding to guide the product to its production centres, to ease the problem of production planning against commitments and orders?

General influences

Delivery reliability will never just happen, it must be planned in advance and be based on accurate information, processed with speed to provide accurate facts on which management can take decisions. Plan the work and work the plan, leaving management free to deal with those items which fail to meet the plan.

Improving delivery performance is not easy; it must involve the whole company. It will highlight many problems, but with determination it can be done, with many benefits to management, staff and employees, apart from improved profitability.

Needless to say, any changes to be made must be explained to middle management and all employees, and their constructive criticism invited. They are the people who will have to implement and operate the plan. The plan must be sold to them and they must be fired with belief in it and have the determination to see it through.

Labour mobility

Delivery performance is a *total company matter* and not only involves management but may also involve changes in traditional or agreed practices. Wages structures or existing working practices may inhibit the mobility of labour within a factory, and if so, there should be negotiations aimed to change them by mutual agreement.

Any review of employer/employee relationships, is, however, outside our terms of reference.

C Questions for the customer

2.20 (i) The main responsibility for poor delivery performance rests with the supplier, but do you know that you can be responsible?

(ii) Do you, in effect, place contracts:

(a) without knowing precisely what you want?

(b) or which are unnecessarily incomplete in technical details, leaving the engineers to settle these?

(c) or which are subsequently amended?

As a result, details are sometimes not finalized even by the delivery date you requested, and the final cost of amendments may be out of all proportion to the future financial benefits to yourself. Every alteration takes time to process through the manufacturers' administration, design and purchasing sections, and further time for the sub-contractor, and adds to the risk of confusion and error causing further delays.

(iii) Do you connive with the supplier at specifying delivery dates which you both know to be neither necessary nor feasible?

(iv) Do you press the supplier to confirm an unreasonable date?

(v) Do you really know what delivery dates you need? How often have you pressed for early delivery and then left the goods in your stores or in work in progress or with the supplier for long periods?

(vi) If you do not know when you want the goods and demand unreasonable dates, and then cause delays by masses of amendments, how can you expect the supplier to believe any date you ask for?

(vii) Do you really require the variations from standard that you request, and are you prepared to pay the real cost of these?

(All too frequently the demand for 'specials' disrupts the production flow of a factory, incurring very considerable overhead cost and producing poor delivery performance). (See also paragraphs 1.19, 1.20).

Appendices

Appendix A Delivery performance and profitability

The following simplified examples are designed to illustrate the higher profitability which can be achieved by a true integration of operations resulting in better control, improved layout, quicker throughput, lower stocks and work in progress and quicker and more reliable delivery. They are based on the actual operating experience of companies and bring out clearly the possible losses or extra profits involved.

Column A of Table 1 shows sales scheduled for 12 months as £1 million bringing in profits of £74,000 at a return on capital of 8 per cent.

Column B shows the effects on profits of failure to meet this planned production schedule and allowing deliveries to slip by one month. The loss of potential profit involved is £41,500 (*ie* £74,000 minus £32,500) equivalent to a reduction in return on capital from 8 per cent to 3·6 per cent.

This takes no account of loss of customer goodwill, whose long-term effects on profitability can be serious.

Table 1 Delivery performance and profitability £'000

	Deliveries as originally planned		*Deliveries delayed by one month*		*Deliveries maintained, but quicker throughput*		*Further potential improvement on basis of C*	
	A		B		C		D	
Sales (12 months)		1,000		916		1,000		1,090
Raw materials and bought out finished goods	450		415		450		495	
Direct labour	60		55		60		65	
Factory expenses	150		150		150		150	
Total works cost		660		620		660		710
Gross income recoupment		340		296		340		380
Technical costs	50		50		50		50	
Selling costs	100		100		100		100	
Administrative costs	80		80		80		80	
Costs of holding stock and WIP	36		33.5		18		19	
		266		263.5		248		249
Net income/recoupment		74		32.5		92		131
Employed capital								
Land, buildings and plant		250		250		250		250
Raw stock and bought out finished goods	80		80		40		44	
Work in progress	300		265		100		109	
Finished stock	100		100		100		100	
Total stocks		480		445		240		253
Debtors less creditors		200		200		200		240
Employed capital		930		895		690		743
Profit as % of employed capital		8%		3.6%		13.3%		17.6%

In Column C we show the effect, even without any increase in production, of improvements in the organization of company operations, *eg* introducing the cellular grouping of machine tools*, improved control and scheduling, reduced throughput time, *etc.* Stocks and work in progress are reduced because 10 machines are produced every month instead of 30 machines every three months. The volume of raw stocks has been halved and there is an even more substantial reduction in the volume of work in progress. As a result the cost of holding stocks and work in progress has been halved. Without any increase in sales this increased efficiency brings about an increase in profits of £18,000 and an increase in the return on capital from 8 per cent to over 13 per cent.

Shorter and more reliable delivery times are also likely to improve the company's competitiveness, increase its goodwill with its customers and ultimately win it more sales. No attempt has been made to quantify these benefits but they can be substantial. Indeed, some of the possibilities are indicated by the example in Column D. In that case, as a result of improved organisation, the company has been able not only to achieve the shorter deliveries achieved in Column C but also to increase its production capacity and consequently its sales. As a result profits rise by a further £39,000 and the return on capital is boosted to 17·6 per cent.

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*For details see Appendix B.

Appendix B Cellular grouping of machine tools and quicker throughput

We have referred to the dramatic benefits accruing from the cellular grouping of machine tools and it will be helpful to explain what we mean by this. The conventional machine shop for batch production has lines of lathes, milling machines, etc. with a great clutter of components waiting to be machined. Parts piled on the floor represent 'dead' money. The long delay in their processing often leads to further delays in the acquisition of bought-out components with the result that the final assembly and eventually the delivery date slips back. Excessive stocks and work in progress, slow throughput and a high working capital/sales ratio are inherent defects of the traditional machine layout. This makes it harder to carry overheads.

With cellular grouping, product piece parts are grouped (by coding) to the key machine through which they pass and in sequence to minimise tool changes. All ancillary machines required for this piece part group are adjacent to the key machine and probably linked by conveyor. Once a component starts its first operation it progresses through the others to its final state, ready for assembly. This concept necessarily leaves auxiliary machines not continuously fully loaded, but the men who work the group of machines are, because they move from one machine in the group to another as the products demand. It may also result in the need for two identical machines in different cells, both of which may be loaded below 50 per cent. But it simplifies administration, in that only the capacity of the key machines and the loading of them needs to be measured; factory processing between machines is eliminated; much material handling is eliminated; work in progress is drastically reduced; and throughput time is decreased. These advantages will almost invariably outweigh the cost of lower machine utilization.

We believe that reduction of work in progress, and consequently of the time that components sit idly anywhere in the factory, is a major necessity for improved delivery performance, both as to reliability and length. It must, however, be accepted that the cellular grouping system necessitates:

(i) apparent surplus plant (of simplest character to simulate multi-head sophisticated machines) to cope with variations in short-term product requirements;

(ii) mobility of labour to move to the machine groups required to meet the immediate demand.

In addition to cellular grouping, it may still be necessary to retain one factory section set up on traditional lines to produce all those components which do not suit the key machines and their related ancillaries. But this now becomes a small unit and is controllable as the completion dates on traditional methods since the quantities of pieces called off are generally to match the piece part output from similar groups.

To facilitate this grouping a system of parts classification is necessary. The existing parts numbering system may have grown up to meet the requirements of the design section and have developed haphazardly.

It is unlikely to be suitable for purposes of production planning and a new system bringing functionally similar items together will be necessary. Where, however, a computer is available or there is electronic punched card data processing it may be preferable to retain existing part numbers and add suffix codes to the data processing to suit production requirements.

Cellular grouping may not be the answer to poor delivery performance in all companies but the benefits cannot be over-emphasized and should be carefully investigated. Where it is introduced it will provide a powerful motive to improve other aspects of integrated operations because a company with these potential benefits could not afford to see them dissipated by poor production planning and control, or an inadequate data processing system, defective forecasting etc. There is growing interest in cellular grouping as manufacturers increasingly realize its tremendous potential. In the Mechanical Engineering EDC report *Production Planning and Control*,* Serck-Audco describe the benefits they have derived from manufacturing in cells; and Mr D T N Williamson has powerfully argued the advantages in a paper recently presented to the Institution of Mechanical Engineers. The relevant sections of this important paper are reproduced below by permission, and merit careful study by board and senior management.

Grouping of machine tools in cells

(Extract from James Clayton Lecture to the Institution of Mechanical Engineers, Wednesday, 27 March 1968.) *'The pattern of batch manufacture and its influence on machine tool design'*, by D T N Williamson FRS.

Production organization

The basic principles of quantity production, using interchangeable parts, were applied in France by Le Blanc and Bodmer, and in the United States of America by Whitney, in the late 18th century, but the foundations of modern mass-production techniques were laid with the Brunel-Maudslay block-making plant. Later in the 19th century small-arms companies in the USA *eg* Colt, Smith and Wesson and later Winchester, started to show the propensity for the development of machinery for large-scale production that has characterized American industrial growth.

The large-scale manufacture of sewing machines, typewriters, bicycles and clocks developed in the second half of the 19th century, and the impetus steadily grew until Henry Ford produced the Model T in 1908, which really set the seal on the mass production era. Special-purpose tools culminating in today's complex transfer machines were devised, along with the conveyor-type material-flow techniques which characterize large-scale manufacture. The Swiss were active in revolutionizing the watch industry with elegant special-purpose machine tools.

The notable feature of this area of manufacture is that, as the invention of a new product gave rise to a demand, the technology and organization of manufacture were evolved together to meet and further stimulate the demand.

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Batch manufacture

The pattern in batch production, on the contrary, has been one of stagnation, and from the results it must be concluded that no one ever had time to stand back and discern the wood from the trees. Various improvements have taken place in the individual machine tools which are used, particularly in the period 1920–40, where strengthened designs were evolved to take advantage of newly developed cutter materials, and new and exotic machine tools of a peripheral nature have been devised, but the accent has always been on *tools*, and the mainstream *organization* in 1968 in all countries is broadly similar to what it was in 1868. Worse than this, the growth in sheer size of batch manufacture has produced a state of affairs which is in many respects inferior to its smaller 19th century counterpart. The small workshop of those days was a tightly knit entity, where each person knew what the other was doing, and each either completed a component himself, or made his contribution in the full light of what the others had done. With this close co-operation, defects and bad technique were brought to light and quickly corrected, and it is to be expected that mutual expertise developed quickly.

It might have been logical to think that, if such an effective organization were to be increased in size, a parallel would have been drawn with biology, where the cells of a living organism do not themselves grow in size, to form one big cell, but duplicate themselves as the organism grows. When abnormally large cells do occasionally form, it presages cancerous growth, and usually results in the eventual death of the organism. Instead of growing in size, as would have been logical, by adding self-contained manufacturing cells of optimum size, which would have preserved much of the original character of the small workshop, whilst increasing the total output to any desired degree, the modern batch production factory has just grown bigger geometrically, with lines of milling machines and lines of lathes and lines of drills, and mounting stacks of parts between the lines, waiting to go from machinist to machinist, each of whom has never seen it before, and after carrying out one or two operations, will never see it again! By this enlarged structure the most valuable commodity which a factory can possess, good communication, is destroyed by treating men simply as drawing readers and handle turners, work most suitable for electronic automatons, and largely ignoring their most valuable and difficult-to-imitate capability, that of co-ordinating from memory and experience. Errors go undetected until the final stage of manufacture, and wasteful work-planning will remain undetected, because no one ever sees the whole process of manufacture of a component from start to finish, unless something goes seriously wrong, in which case there *might* be an investigation. The multiple feedback loops which are so essential for stabilizing a complex process of this nature, and which were inherent in the small workshop, are severed and can no longer operate. Attempts to control this arrangement involve armies of planners and progress chasers and inspectors, whose job it is to route parts through the system or to trace those which are lost somewhere in its needless complexity. It can only be assumed that this organization grew up from a desire to improve machine loading, and in pursuit of theories about the division of labour in an attempt to cope with the dilution of skill that accompanies expansion. Unfortunately, the popular route towards these ends has turned out to be the worst that could have been taken.

The increasing complexity and speed of modern machinery demands higher quality components to give adequate performance and life, and this requirement in Britain has coincided with a serious shortage of skilled labour and consequent decline in the average capability of human productive effort. All engineers are familiar with the fact that two components can look alike, and yet one works and the other does not. The subtleties which make the difference are part of the know-how which determines the capability of an engineering company. These conditions would be expected to lead to a further decline in such capability, and there is evidence that this is happening. Such a decline in an engineering company can only lead to absolute disaster and the eclipse of that company by a competitor, probably at present smaller in size, who has taken advantage of his size to maintain a higher average level of skill. There is a tendency today to equate bigness with efficiency and capability. Here is one area (and there are others) where increasing size inevitably produces absolutely the opposite effect with the present type of organization.

One or two large engineering companies, mainly in the aircraft industry, have maintained their standards by demonic quality control and the tolerance of high scrap levels, but this inevitably results in very high costs and a loss in competitiveness. More and more must come to realize that there is a problem here, fundamental to engineering, which cannot be solved without a drastic change of direction and changed attitude to life. The decline is in full swing now, and it must be halted quickly if we are to survive. There are two phases that have to be tackled simultaneously: the first, to rescue the traditional manufacturing techniques by a change in organization which makes more effective use of the available skill and capital equipment; the second, to create a completely new design and manufacturing philosophy which can gradually take over from the present phase. In this, modern technology would be applied to form an integrated design and manufacturing complex. By these means, at least in certain industries, it will be possible to make an order-of-magnitude change to the efficiency and cost of manufacturing machinery in batches.

Batch manufacture as a process

In viewing small-batch manufacture as a process, it is not easy to separate the manufacturing process from the design process, nor indeed is this desirable. The best results will always be obtained when they are treated as inseparable.

Unlike mass production, where economics dictate that immense effort should and can be put into a product to ensure that its design is optimum from the functional and manufacturing points of view, the majority of today's technologically advanced products are never quite right when they are first manufactured, and modifications are required, not only for this reason, but also to suit customer requirements or conditions of use. Shortage of effort, tight time schedules, material shortages and changes, errors, poor communication and incomplete understanding of other sections of the process all combine to make life difficult, and not infrequently to produce chaos when too many parameters are affected simultaneously. The ideal treatment then would be to study the whole design-production interface as a complex control problem and to arrange appropriate flow patterns and feedback loops to produce the desired effect, but this has rarely, if ever, been done and in any case is beyond the scope of the present paper.

Batch manufacture is almost universally accomplished today by issuing components into manufacture on an 'operation' basis, *ie* the work to be done is split down by planning and work study into separate operations, involving perhaps 5–30 operations per part. Each of these operations is treated as separate and may involve passing the part from one machine or process to another, but even where many of the operations are confined to one machine tool, changes in the set-up or position of the workpiece on the table are very frequent. These changes in set-up mean that the machine tool is not cutting during this period, and the cutting time, expressed as a percentage of the total working time the workpiece is occupying the machine table, averages only 15–20 per cent. Where the component has to be passed from machine to machine, the situation gets much worse, and even with good organization it is rarely possible to manage a large manufacturing shop in such a way that components spend less than one day between operations. In very many firms throughout Britain, the time taken between operations is nearer one week. Even when only a few operations are involved, the queuing problems associated with machine loading give a total component manufacturing cycle which is rarely less than three and not infrequently as much as six months, the average being about 100 days. The ratio of cutting or processing time to the total cycle time is unlikely to exceed 1 per cent, and may be much less.

It will be appreciated that this represents a very large investment in partly finished material, in addition to a serious delay in fulfilling orders. An extremely complex and expensive production control system is required to chase the work from operation to operation, and although a computer can be used to help, it is only a palliative which does nothing to remove the main disadvantages of the system.

This arrangement has clearly derived from the small workshop in the process of industrial expansion, but it is not clear to me why such a remarkably ineffective variant came to be universally selected and accepted. As workshops grew, it is reasonable to assume that skill would be diluted, and to make better use of the available skill it might at first sight appear that, by using a skilled man to analyse the manufacture of a part into a series of simple steps, each separately timed and rate-fixed, and using other less skilled men to carry out these steps, the division of labour criteria were satisfied. In a small or medium-sized workshop with varying levels of skill and with good supervision to speed the movement of parts through the shop, this method may achieve its objective of increasing the average throughput per man at an acceptable cost of increased work-in-progress. In today's large manufacturing units, however, it gets completely out of hand, and the cost of the inventory alone is far greater than any theoretical advantage which could be obtained from the division of labour.

The alternative to the conventional single-unit or 'amorphous' manufacturing organization is 'cellular' manufacture, where the men and machine tools are grouped into specialist units or cells manufacturing one category of component or a very limited range of components. Each component is classified in such a way that it is issued into the cell most appropriate for its manufacture. Such specialization would bring its advantages: on the human side, in familiarity with the components, resulting in more detailed know-how, and a higher concentration of skill: and on the machine tool side, in the ability to use simpler machine tools specially suited to a limited range of components, supplemented by appropriate specialized tooling. An operator in a cell could use more than one machine tool, and in general there would be more machine tools than operators. In some cases these machine tools would be adapted to speed the types of operation most often required. Provided that the cell was self-contained in all respects, the progress of a part through it would be very swift. The huge queuing problem associated with 'amorphous' manufacture would disappear, and with it much of the inventory represented by material waiting between operations. The average cycle time would drop from 100 days to about 10–15 days, or even lower, and from this fact alone there stems a new flexibility which, if exploited, could bring many advantages to the overall operation of a company.

In any batch manufacturing process the major factors which require to be optimized are shown in Table 2. All these major factors are interrelated: almost all can be quantified, and production organizations can be compared in their light. Clearly, only in a specific case can values be assigned to these factors, and the reader will perhaps forgive the somewhat woolly comparison that is made between the 'amorphous' and 'cell' arrangements. Only arbitrary values can be put on good communications and team spirit, but anyone with experience knows that these factors have a value beyond price, and in the limit they determine the flexibility, capability and efficiency of the organisation.

Table 2 Factors important when comparing production systems, showing qualitative comparison between 'amorphous' and 'cellular' systems

		Amorphous arrangement	*Cell arrangement*
1	Capital investment/unit output	High	Lower
2	Labour cost (incentives and rewards)	Similar	
3	Preparation and supervision cost	High	Low
4	Inspection cost	High	Low
5	Inventory cost (stocks and work in progress)	High	One-fifth
6	Space	High	Lower due to lower stocks
7	Speed (cycle time for part manufacturing)	100	10–15
8	Use of available skill	Poor	Good
9	Communication	Poor	Excellent
10	Machine tool loading	Good	Probably less good
11	Discipline and team spirit	Poor	Excellent
12	Ease of control	Difficult	Easy
13	Minimizing waste	Difficult	Easier
14	Material flow	Costly	Simple
15	Accuracy of costing	Must be averaged	Precise

The term 'good communication' covers the accurate transfer of spoken, written and unwritten information. A drawing is the traditional universal method of transferring information from design to production, but no drawing ever contains all the nuances and know-how which go into a component and its relationship with other components of the end product. Much of this is left un-said and is embodied in the expertise of the company, *ie* of the company's staff. But company staff changes, and hence the expertise is constantly changing. The more unspecialized the machinists become (*ie* the wider the range of parts they are expected to cope with), the more likely they are to slip up, or to have a gap in their knowledge and understanding of what is really required. Everyone can list dozens or even hundreds of cases at all levels where trouble has resulted from the inaccurate transfer of information or the incorrect assumption that someone 'understood what was required'. The widespread idea that this experience can be replaced by written planning instructions is sheer nonsense.

These never can and never will be an adequate substitute for the feeling for the 'correctness' of a part, which derives from an intimate understanding of its functional requirements. Clearly everyone in an organization cannot have such an understanding, but if manufacture were arranged in specialized cells which completed a limited range of components, the members of the appropriate cell could, particularly the cell leader, who sees the whole process from start to finish, and can intervene as necessary. It must be clear that such an arrangement is a world apart from the present situation, and the effect of the sense of esprit de corps, capability and responsibility which it would inject into a company cannot be overstated. These qualities, which can be summed up as 'atmosphere', are what distinguish the outstanding companies from the 'also rans'.

Part classification and the optimum cell arrangement

Once the principle has been established that centralized 'single cell' or 'amorphous' organization is wrong, the question arises as to how 'crystalline' or multi-cellular a given organization should be, and what the criteria should be for subdivision. Attempts have been and are being made to use this as a basis for design selection and the production grouping of machine tools. Numerical shape classification systems of considerable ingenuity (and in some cases hair-splitting pedantry) have been devised, originally with the idea that, by reference to a master parts file, a designer could avoid redesigning a part that already existed. In my view, this is a complete misconception of the object of design, and the logical outcome of its use would be to stultify design, by attempting to turn a creative process into one of assembling existing parts, in all probability at greater design and manufacturing cost, because the tendency would be to use two 'standard' parts where one optimally designed part would do. It puts a premium on the suppression of novelty, which is clearly a disastrous thing to do, and similarly it perpetuates out-of-date manufacturing methods. It should always be possible to design a better and cheaper component to fulfil the same function, even after a short gap of only four or five years.

The term 'group technology' (which means different things to different people) has been coined to refer to the use of part-numbering principles to classify components for manufacture, usually in the context of an 'amorphous' system. The aim is to improve machine tool loading and reduce set-up time by assembling larger 'economic batches' of components that look alike, although they may actually be very different, a process sometimes known as 'variety reduction'. In favourable circumstances this may be a step in the right direction, although the increased inventory that 'economic batches' necessarily entail could easily nullify the economic value of any advantage in productivity. This method does nothing to improve communication or expertise, and must be clearly differentiated from the cell system, where the batch size is infinite and where manufacture can be considered almost in continous-flow terms.

I am doubtful if geometrical shape is the best method of classification, and even more doubtful about the necessity of rigorous subdivisions. It is probable that, in a given organization, the number of component classifications need not exceed 20 or 30, in which case the allocation of an individual component to a group becomes obvious, and complex decimal part-numbering systems are then only an expensive and time-consuming exercise in numerical semantics. There is a great deal to be said in favour of simple classification by function. Conditions of use are far more important in manufacture than geometrical shape. Shape classification systems would have difficulty in distinguishing a barge-pole from a retaining pin, or a nail from an exhaust valve, yet no one would think of making these in the same cell, far less on the same equipment.

The use of part-number classification systems as a production aid has much more to recommend it, but it is by no means an ideal arrangement where the flow of work is controlled by a computer. Under present conditions parts are invariably numbered at the drawing stage, but all the information that could be of importance to the manufacture of the part is not available at that stage, but is generated later. Part-numbering can be a tedious process which can easily create a bottleneck in a swiftly moving organization. In my opinion it is an anachronism conceived in the era of mechanical data processing and rendered obsolete by computer developments. A better solution, therefore, is to give the part a simple serial number, followed by a two-digit classification on the lines of Table 3, and to arrange that all the other information it is required to know about it is stored in the computer under that number. This information can be made as comprehensive as required and updated from time to time. If a geometric or any other type of sort is required, it is a simple matter to provide for it.

Table 3 Functional classification of components

01	Transmission items: gears, sprockets, timing belt pulleys, ratchets
02	Cams
03	Shafts
04	Mainly turned parts
05	Covers and light structural parts and mainly fabricated items, formed sheet metal items
06	Fasteners and associated 'indent' type items
07	Levers, cranks and connecting rods
08	Brackets
09	Milled parts with holes
10	Gearbox housings
11	Beds and large structural members
*12	Hydraulic manifolds and valves
*13	Rods and hydrostatic bearings
*14	Machine tool structural castings
†15	Fluted drums
†16	Garnitures and slideways
17	Parts of unusual or awkward nature
18	Plastic parts (injection moulded, cast or built/laid up)
19	Woodwork
20	Proprietary items bought complete
21	Cableforms and looms, wiring harnesses, electronic chassis
22	Etched and chemically machined items (including printed boards)
23	Electronic circuit cards
24	Electronic transducers

01–11 Basic mechanical engineering cells.

*Cells special to Molins machine tools.

†Cells special to Molins tobacco machinery.

Functional classification has the following advantages:

(1) It groups parts in a natural way and draws attention to their end use in finished equipment.

(2) A similar range of materials is usually used by a given manufacturer for the parts within a given group.

(3) Grouped parts tend to have similar wear, fatigue and other working conditions, and to require a similar range of skill, finish and accuracy.

(4) The nuances and 'in-house know-how' are well understood and intensified within the groups and cross-fertilized between them.

(5) This method gives the maximum psychological advantage of 'playing a part' that it is possible to have, without groups making complete subassemblies. 'We make all the gears, or all the levers, or all the brackets' has more sense of purpose than 'We make all the shapes in Group A'. This is a factor not to be dismissed lightly.

(6) If a component is found to be wrong on assembly, it is much easier to have it rectified by direct communication between assembly and cell leaders.

(7) All the foregoing reasons contribute to improved communication—the paramount reason for grouping. In my opinion, if necessary, other factors such as machine tool utilization should be sacrificed to obtain the best possible communication, as this will bring benefits which will more than pay for anything that is lost in this way.

Typical functional classification

Functional classification is clearly dependent on the products being manufactured, but in each type of industry there will be common ground. Product diversification may increase the number of classes, but most companies, if they are wise, diversify in fields where their technology naturally leads them. If new classes have to be created, this only underlines the need for special skills.

A list of manufacturing cells, including mechanical and electrical, suitable for tobacco machinery and machine tool manufacture, is shown in Table 3. Most engineers will recognize the common ground, will wonder what one or two are for, and will think of some special one to add for their own products.

Size and composition of a cell

The size of a cell must depend to some extent on its function, but in general to achieve the object of cellular division it should not exceed 10 people, as experience suggests that this is the maximum number who can work and communicate closely together, and be controlled by a leader. If conditions permit, 6 would be better than 10.

On the assumption that a company needs about 25 types of cell, then a given cell type should be multiplied to cope with the total manufacturing load, as required by its average variety distribution. Advantage can be taken, when duplication is necessary, to specialize further, for example by having basically similar cells of differing size ranges, or perhaps quality or accuracy, which would determine the sizes and types of tools used. An element of competition can be introduced between similar cells to stimulate method improvement.

It is usual for the total manufacturing load and its variety to fluctuate from time to time, and this brings out the main disadvantage of the cell method, that of keeping cells evenly loaded. If the fluctuations can be limited to about 20 per cent, no difficulties are likely to arise greater than those which confront the amorphous arrangement. Surplus capacity in a cell can be utilized either to finish components in an adjacent size category or to finish components of the nearest similar variety. As a last resort work can be allocated between cells on a part-finished basis. This, of course, is no better than the amorphous arrangement, but neither is it worse, and its disadvantages now only apply to the surplus instead of the total volume. A fast computer scheduling system would be of great value in dealing with load fluctuation, with specialized 'software' to deal with the exact problem encountered with a given arrangement, written in such a way that it could be modified on the basis of experience.

Plant utilization

The specialized nature of a cell allows a fresh approach to be taken to the provision of machine tools. No longer are we looking purely for universal tools, although these are still required, but also for specialized tools and set-ups tailored to speed the type of operations usually performed. Cells will greatly stimulate ingenious ideas to cut corners and save time and money, ideas which are at present stifled by the weight and variety of the work load. Those familiar with the single-minded purposefulness and expertise of the small specialized tooling workshops which surround Detroit, or the aircraft subcontractors in California, will know what is meant. The stimulation of this attitude would alone justify the cell system.

It will be convenient to have items of plant that are not fully utilized under normal load conditions, but which justify themselves by their convenience and swiftness when they are used. This is clearly of no account when small low-cost tools are involved, and six people would operate perhaps 10 tools. One should not necessarily shrink from the apparently inefficient use of expensive machine tools if their effectiveness when they are working is high. Each case must be treated on its merits, remembering that the reduction in inventory will pay for much more capital equipment. One of the very great advantages of cellular organization is the inherent accuracy of costing, since plant, labour and overhead costs are precisely known, and need no longer depend on averages of doubtful validity.

Implementation

It must be admitted that the foregoing is of a theoretical nature, and I do not know of any large-scale manufacture of a complex nature that has yet been organized on this basis. There are, however, some interesting portents from experimental cellular organizations, and in every case known to me these appear to be successful. Probably the outstanding example in the UK which is fully described in a Mechanical Engineering EDC booklet, is that of Audco Ltd, where these principles have been applied to the manufacture of a wide range of taper-plug valves. The summary of results quoted in this publication (Table 4) speaks for itself, and reflects great credit on the directors of this company, who transformed it out of all recognition over a period of four years.

Table 4 Performance improvement at Audco following implementation of integrated cellular manufacture

Sales	Up 32 per cent
Stocks	Down 44 per cent
Stock/sales ratio	Down from 52 per cent to 25 per cent
Manufacturing time	Down from 12 weeks to 4 weeks
Overdue orders	Down from 6 weeks to under 1 week
Despatches/employee	Up, about 50 per cent
Capital investment	Cost recovered 4 times by stock reduction alone

Table 4 (cont)	**1961–62**	**1962–63**	**1963–64**	**1964–65**	**1965–66**
Net despatches, £M	2.220	2.184	2.585	2.922	3.152
Total personnel (average)	1,001	952	903	941	984
Total wages and salaries, £	714,467	705,911	752,121	843,671	947,962
Despatches per employee, £	2,218	2,294	2,863	3,105	3,203
Average income per employee, £	714	742	833	897	963

These results were achieved over a period of approximately four years.

A similar effort by other managers in the engineering industry would transform Britain's economy. Of course it can, and will, be said, with some truth, that all companies are not alike. In many companies it would be more difficult to achieve the success that Audco has achieved, but in others it could be easier. Most companies have the idea that they are unique, and that their problems are very difficult and special. This is frequently used as an excuse for doing nothing, rationalized to 'leaving well alone'. I suspect that it is this attitude to life, rather than any technical difficulty, which inhibits such imaginative reorganization.

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In addition, there are many standard text books on techniques available, *eg*

Principles of Production Control J L Burbidge, MacDonald and Evans 50s.

A Guide to Supplier Quality Assurance in Engineering Institution of Production Engineers 10s 1966.

Management Today—Annual Review of Techniques 10s 1968.

Membership of the working party

Delivery performance working party

Chairman	
E B Leach	Formerly chairman, Serck Audco
Members	
A C Ball	Director, Hayward-Tyler Ltd (member of Stone Platt Industries Ltd)
J P Dainty	Ministry of Technology
D B Drage	English Electric Co Ltd
J Donkin	Director, Archibald Kendrick & Sons Ltd
D J Falvey	National Economic Development Office
G Harris	Group purchasing controller, Firth Cleveland Ltd
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S Kerr	British Productivity Council
V W Oubridge	Department of Economic Affairs
D F Penny	Sales manager, Steam Generation & Power Plant Division, Clarke Chapman & Co Ltd
W Stockdale	Chairman, Lightnin Mixers Ltd
D T N Williamson FRS	Research director, Molins Machine Co Ltd
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J F Safford	National Economic Development Office
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C Hanley	National Economic Development Office

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NATIONAL ECONOMIC DEVELOPMENT OFFICE

BETTER DELIVERY

How to make delivery promises more reliable; reduce delivery times; and improve profitability

Report of a working party of the Economic Development Committee for the Mechanical Engineering Industry

27 AU 1969

LONDON
HER MAJESTY'S STATIONERY OFFICE 1969

The Economic Development Committees are composed of representatives of the three parties involved in industrial and economic development—management, trade unions and government. Their secretariat is provided by the National Economic Development Office, which is an independent, publicly financed body. This report has been prepared for publication by NEDO *on behalf of the* EDC *for Mechanical Engineering which is solely responsible for its contents. For administrative convenience the booklet is printed and published through* HMSO.

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Preface by the working party

We were appointed a working party representing makers and users of plant and machinery, the Government and the National Economic Development Office, as a result of a decision by the Mechanical Engineering EDC that it was urgently necessary to study ways of improving the competitiveness of our mechanical engineering industries through improved delivery performance.

We first met in March 1968 and the terms of reference we have adopted are:

(a) To define board and management attitudes, methods and organisation for improving the reliability and length of delivery, mainly in batch production of finished products or components;

(b) To consider means of influencing boards and managements to adopt such attitudes, methods and organisation.

We did not consider it practicable in one report to examine all types of activity, from mass-produced consumer products to specially designed one-off projects. This is why this report has been aimed primarily at companies or establishments whose main activity is batch production (the predominant practice in mechanical engineering) and employing, say, 150 to 2,000 people. Nevertheless, many of the points covered will be applicable to other types of operation.

The membership of the working party is shown on page 32.